BIOCIDAL AND ALLELOPATHIC PROPERTIES OF GRAMINEOUS CROP RESIDUE AMENDMENTS AS INFLUENCED BY SOIL TEMPERATURE

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ABSTRACT

Controlled environment experiments were done to test the effects of amending soil with dried residues of certain cultivated gramineous plants, including wheat (*Triticum aestivum* L. cv. Yolo), barley (*Hordeum vulgare* L.cv. UC337), oats (*Avena sativa* L. cv. Montezuma), and triticale (*X Triticosecale* Witt.) at ambient temperature of 21-24°C and at an elevated, but sublethal 38°C day/27°C night regimen on survival and activity of the fungal plant pathogens *Sclerotium rolfsii* and *Pythium ultimum*, and the pathogenic nematode *Meloidogyne incognita.* Addition of wheat and barley amendments to soil without heating resulted in significantly reduced tomato root galling by *M. incognita*, and all amendments except triticale reduced germinability of fungal pathogens after 7 days incubation. When gramineous soil amendments were combined with sublethal heating, nematode galling was reduced by 99-100%, and recovery of active fungi was reduced by 84-100%. Some evidence of phytotoxicity arising from the soil amendments was noted in the bioassayed tomato plants.

INTRODUCTION

There has been considerable scientific and commercial effort recently in developing cover or rotational crops which provide some measure of management potential for soilborne pests. Much of the interest has been in biofumigation (Angus et al., 1994) using members of the cruciferae (Gamliel and Stapleton, 1993) which produce bioactive glucosinolates (Duncan, 1991). Other plant taxa have been tested, including *Allium* spp. (Stapleton et al., 2004) and various gramineous taxa. Many of the agronomic grasses and cereal grains have been shown to possess antibiotic and/or allelopathic properties (Creamer et al., 1996; Davis et al., 1996; Doohan et al., 2000; Widmer and Abawi, 2000). Although useful levels of pesticidal activity have been demonstrated from gramineous plant residues, undesirable instances of phytotoxicity to subsequent crops also have been reported (Guenzi et al., 1967; Holmes and Mayberry, 1996; Mitchell et al., 2000; Waddington, 1978; Weston et al., 1989).

Increased cropping of gramineous plants in California may result from the current interest in augmenting the national fuel supply with bioethanol production. To evaluate potential rotational biofumigation activity, soil amendment with dried residues of several cultivated gramineous crops were tested in controlled environment studies. Target pest organisms were the nematode and fungal plant pathogens *Meloidogyne incognita, Pythium ultimum* and *Sclerotium rolfsii*.

MATERIALS AND METHODS

Laboratory Study - Apparatus and Inoculum Preparation

The controlled environment experiments were conducted in covered containers as previously described (Gamliel and Stapleton, 1993) to test the effects of soil amendment with several preparations of gramineous plant residues and two temperature regimens. Survival and activity of the plant pathogens *M. incognita*, *S. rolfsii*, and *P. ultimum* was evaluated. The soil used was Hanford fine sandy loam (46% sand, 45% silt, 9% clay; pH 7.4) naturally infested with *M. incognita* (ca. 150 second-stage juveniles [J2] per liter of soil) and *P. ultimum* (ca. 29 propagules [oospores] per gram of soil). Laboratory-grown sclerotia of *S. rolfsii* were added to the soils in mesh bags (30 sclerotia per bag) prior to treatment. Soil for treatment was loaded into widemouthed, 2 l capacity glass jars sealed with metal lids. Four sub-samples of soil per test were treated by incubation in a single modified, Wisconsin-type waterbath with sub-lethal diurnal temperature maximum and minimum of 38°C and 27°C, respectively, while others were maintained in a similar waterbath set at ambient temperatures of 21-24°C.

Gramineous Amendments

The gramineous amendments used in these tests were dried and Wiley-milled vegetative tissues of: wheat (*Triticum aestivum* L. cv. Yolo), barley (*Hordeum vulgare* L. cv. UC 337), oats (*Avena sativa* L. cv. Montezuma), and triticale (*X Triticosecale* Wittm.). All amendments were incorporated into soil at a concentration of 1.9% (w/w), an approximate quantity of residues tilled into soil at the end of a cropping cycle in commercial field production.

Determination of Treatment Effects

Effects of treatments on *M. incognita* were estimated after 7 days using a bioassay procedure. Treated soil was aired in open plastic bags for 24 hr following the incubation period, then placed in two 10-cm-diameter pots per replication. A single plant of a susceptible tomato cultivar (*Lycopersicon esculentum* L. cv. Cherry Belle) was transplanted into each pot and the pots were maintained in a glasshouse at 30°C maximum and 21°C minimum.

After six weeks growth, roots were washed and an arbitrary gall rating was made (0-4 scale, where 0 = no galls evident and 4 = 75-100% of roots galled by visual examination). Some evidence of phytotoxicity arising from the soil amendments was noted in the bioassayed tomato plants. Sensitivity of *S. rolfsii* to treatments was determined after 7 days incubation, as previously described (Gamliel and Stapleton, 1993), by retrieving and surface-disinfesting the 30 sclerotia from the experimental containers, then placing them on PDA agar plates to determine germinability (Gamliel and Stapleton, 1993). After the 7 day treatment period, effects on *P. ultimum* were determined by sampling soil from containers, then air-drying and plating it on a selective medium as previously described (Gamliel and Stapleton, 1993). At least two sets of assays were performed for each amendment and soil heating combination tested.

Data Analysis

The *in vitro* experiments were used as replications for comparing amendments and temperature regimens. For each experiment, subsamples were averaged for each amendment by combining results from the warmer/cooler temperature treatments. All amendments were not included in each experiment, but each experiment had a nonamended control treatment. Consequently, the number of replicates differed among treatments. Data for pathogen survival and activity taken as percentages of the control treatments were transformed, using the arcsin of the square root or the base 10 logarithm to homogenize the variances. Analysis of variance was run for just the controls to compare experiments. Analysis of variance was also run to test the effects of amendments, temperature regimens, and their interactions. Contrasts of interest were calculated to test amendment versus control, and the interaction of amendment versus control and temperature. Fisher's Protected LSD test was used for mean separation of amendments for the cooler and warmer temperature regimens.

RESULTS

Analysis of variance for controls showed that experiments were not significantly different for galling of tomato roots by *M. incognita* or for germination of *S. rolfsii* sclerotia after 7 days. Experiments were significantly different for *P. ultimum* survival; therefore survival of *P. ultimum* after exposure to the various amendments for 7 days was calculated relative to the corresponding nonamended control at ambient temperature for the respective experiment. Post-treatment population assays of each of the test organisms confirmed that the warmer temperature regimen used during the experiments was sublethal. For each of the test pathogens, significant main effects for amendments, soil temperature, and the amendment x temperature interaction were found, with the exception that the interaction was not significant for *S. rolfsii*. The other consistently significant statistic across the range of pathogens was the contrast of amendment versus the control x temperature. Since the amendment x temperature treatment interactions and/or the amendment vs. control x temperature contrasts were significant, LSD tests were used for mean separation of amendments for the warmer and cooler treatments.

Addition of wheat and barley amendments alone gave significant reductions in root galling of tomato due to *M. incognita*, compared to the cooler temperature control, after 7 days treatment. Gall ratings were decreased by 99-100% when any of the amendments were incubated at the higher temperature regimen, with a significant treatment interaction between amendments and temperature. Addition of gramineous amendments at ambient temperature reduced germination of *S. rolfsii* sclerotia after 7 days incubation. Soil amendment with wheat caused the most deleterious effect on sclerotial germination. Incubation at the warmer temperature regimen completely inhibited germination.

Soil amendment with each of the gramineous residues except triticale significantly reduced numbers of *P. ultimum* after 7 days incubation at the cooler soil temperature. Wheat, barley, and oats were equally effective. When the amendments were combined with the sublethal heating regime, the reductions increased to 84-100%.

DISCUSSION

Biofumigation has the potential to significantly contribute to economic control of soilborne plant pests. However, the effects are often inconsistent or insufficient. In the high value, intensively-farmed horticultural crops common to California agriculture, it is unlikely that periodic rotations into bioactive, gramineous plants will provide sufficiently effective or predictable soil disinfestation. Addition of a soil heating component by way of solarization can assist in fulfilling the requirements of growers. Therefore, combination of gramineous soil amendments with solarization is a feasible option for development and implementation. However, since phytotoxicity has been observed following incorporation of gramineous crop residues, thorough testing will need to be done to provide sufficient guidelines for commercial use.

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REFERENCES

Angus J.F., Gardner P.A., Kirkegaard J.A., Demarchelier J.M. 1994. Biofumigation: Isothiocyanates released from *Brassica* roots inhibit growth of the take-all fungus. Plant and Soil 162, 107- 12.

Creamer N.G., Bennett, M.A., Stinner, B.R., Cardina, J., Regnier, E.E. 1996. Mechanisms of weed suppression in cover crop-based production systems. HortScience 31, 410-413.

Davis, J.R., Huisman, O.C., Westermann, D.T., Hafez, S.L., Everson, D.O., Sorensen, L.H., Schneider, A.T. 1996. Effects of green manures on *Verticillium* wilt of potato. Phytopathology 86, 444-53.

Doohan, F.M., Mentebab, A., Nicholson, P. 2000. Antifungal activity toward *Fusarium culmorum* in soluble wheat extracts. Phytopathology 90, 666-671.

Duncan, A. 1991. Glucosinolates. In: Mello, J.P., Duffus, C.M., Duffus, J.H., (eds), Toxic Substances in Crop Plants. Royal Society of Chemistry, Cambridge, U.K., pp. 127-147

Gamliel, A., Stapleton, J.J. 1993. Characterization of antifungal volatile compounds evolved from solarized soil amended with cabbage residues. Phytopathology 83, 899-905.

Guenzi, W.D., McCalla, T.M., Norstadt, F.A. 1967. Presence and persistence of phytotoxic substances in wheat, oat, corn, and sorghum residues. Agronomy Journal 59, 163-165.

Holmes, G.J., Mayberry, K.S. 1996. Adverse effects of sudan grass residue on lettuce stand establishment. Imperial County, CA Ag Briefs, University of California Cooperative Extension, pages 4-5.

Mitchell, J., Summers, C., Prather, T., Stapleton, J., Roche, L. 2000. Potential allelopathy of sorghum-sudan mulch. HortScience 35, 442.

Stapleton, J.J., Molinar, R.H., Mallek, S.B., Ruiz, T.S. 2004. Potential for soil biofumigation using residues of *Allium* spp. in crop rotation strategies. In: Proceedings: California Organic Production and Farming in the New Millenium: A Research Symposium. UC DANR, Berkeley, CA, July 15, 2004, pp. 122-124. Available online at URL: http://www.sarep.ucdavis.edu/organic/CCBCposters.pdf

Waddington, J. 1978. Growth of barley, bromegrass and alfalfa in the greenhouse in soil containing rapeseed and wheat residues. Canadian Journal of Plant Science 58, 241-248.

Weston, L.A., Harmon, R., Mueller, S. 1989. Allelopathic potential of sorghum-sudangrass hybrid (sudex). Journal of Chemical Ecology 15, 1855-1865.

Widmer, T.L., Abawi, G.S. 2000. Mechanism of suppression of *Meloidogyne hapla* and its damage by a green manure of sudan grass. Plant Disease 84, 562-568.